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A Single Phase Transformer less Active Device To Improve Power Quality For Electrified Transportation

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Abstract

A Transformer less Hybrid Series Active Filter (THSeAF) is proposed to redesign the power quality in single-arrange systems with fundamental loads. This project helps the imperativeness administration and power quality issues related to electric transportation, and concentrates on enhancing electric vehicles loads relationship with the system. The control method is intended to expect current symphonious touches of non-guide loads to stream into the utility and redresses the power factor of this later. While, protecting fragile loads from voltage unsettling influences, hangs, and swells begun by the power system, ridded of the series transformer, the setup is invaluable for a mechanical use.

This polyvalent half breed topology permitting consonant disengagement and compensation of voltage turns could absorb or infuse the aide vitality to the system. By convenient examination the project also explores on the effect of get sand delays in the consistent controller steadiness. The reenactments and exploratory result introduced in this work were finished on a 2kVA lab prototype showing the suitability of proposed topology.

INTRODUCTION

The guess of future Smart Grids related with electric vehicle charging stations has made genuine stress on all parts of vitality nature of the power structure, while expansive electric vehicles battery charging units[1,2] effetely influence control dissemination system consonant voltage levels. On the other hand, the advancement of music supported from nonlinear weights like electric vehicle drive battery chargers[4,5], which without an uncertainty impactely influence the power structure and influence plant equipment, should be considered in the change of present day lattices. Besides, the extended rms and pinnacle estimation of the deformed current waveforms increment warming and misfortunes and cause disappointment of the electrical apparatus. Such wonder feasibly decreases structure profitability and should truly been tended to [6.7].

In addition, to ensure the point of common coupling (PCC) from voltage mutilations, using dynamic voltage restorer function is exhorted. An answer is to lessen the contamination of energy gadgets based loads straightforwardly at their source. Albeit a few endeavors are put forth for particular defense consider a nonexclusive arrangement is to be investigated. There exist two types of dynamic power devices to defeat described power quality issues. The main classification are series dynamic channels including crossover type ones. They were created to eliminate current music delivered by non-linear load from the power framework. Series dynamic channels are less provided food than shunt type of dynamic channels [8,9]. The favorable position of series dynamic channel contrasted with shunt type is the inferior rating of the compensator versus stack nominal rating [10]. However, the multifaceted nature of the design and necessity of a disengagement series transformer had decelerated their industrial application in dissemination frame work. This condition classification was created in concern of addressing voltage issues on touchy loads. Commonly known as Dynamic voltage restorer (DVR), they have a comparable design as of Series dynamic channel. These two categories are not the same as each other in their control principle. This difference relies intentionally of their application in the frame work.

Consequently, to beat these disadvantages a half breed control channel which is a combination of dynamic and latent channels is proposed [3]. This paper discusses how a combination of both dynamic and latent channels is a sparing answer for control quality change. To enhance the attributes of detached channel and furthermore the framework, the dynamic channel ought to be controlled legitimately. There are distinctive control techniques for this reason. The main point of any control method is to make dynamic channel inject a voltage in to the framework that compensates the sounds. To accomplish this yield voltage of the dynamic channel is controlled with the end goal that it is equivalent to pre-ascertained reference esteem. The dynamic channel is controlled better with instantaneous responsive power hypothesis.

This is presented in [4] and it discusses the distinctive control calculations from the details of instantaneous responsive power hypothesis. Finally it concludes that vectorial based hypothesis yields better results with sinusoidal streams when contrasted and different calculations. The control of series dynamic in conjunction with shunt uninvolved channel using double instantaneous responsive power vectorial hypothesis is presented in [5]. In this paper the proposed hypothesis is approved by simulating it in MATLAB SIMULINK condition. The proposed control procedure is reenacted for both balance and unbalanced load conditions.

DESIGN OF HYBRID FILTER

The channel is utilized to decrease the music and enhance the power quality. The channel that is associated with the framework ought to be controlled adequately to such an extent that its response qualities are as desired. Among the distinctive accessible channel designs, cross breed control channel with series APF and a parallel detached channel is utilized as a part of this venture. The control circuit of the series associated APF is designed such way that the voltage injected by the APF compensates the sounds and furthermore enhances the performance of the shunt associated detached channel. The control system of the half breed control channel is explained in detail in this section.

DESIGN OF SERIES ACTIVE POWER FILTER

The series APF utilized for the power quality change is acknowledged as a Voltage Source Inverter (VSI) [8]. It can be a three-phase VSI or three single-phase VSI" s can likewise be utilized. The VSI is associated in series with the source impedance through a matching transformer. The circuit outline is appeared in Fig 1. A capacitor is utilized at the input if the VSI to give consistent input voltage to VSI.

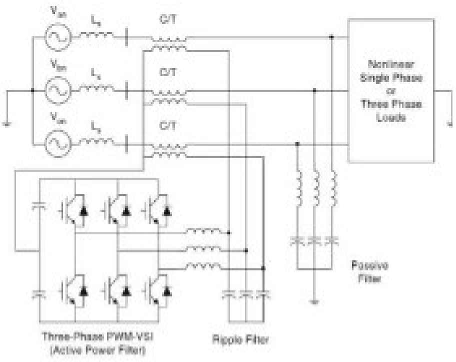

Fig .1 Overall circuit diagram of the hybrid filter.

A passive filter is additionally associated at the PCC. This filter is tuned to eliminate higher request sounds [9] [10]. In certain cases there might be at least two LC branches tuned to eliminate particular request sounds (especially fifth and seventh). A swell filter is utilized as a part of series with VSI.

MODELING OF SERIES ACTIVE POWER FILTER

The modeling of the series Active Power Filter is necessary so as to control the filter. In this venture, the modeling of the series APF which is nothing yet a three-phase VSI is completed in 2-ф stationary reference outline (α-β). Subsequently, the three phase quantities, voltage and current vectors, are changed into α-β co-ordinates by using Clarke's Transformation [11] [12].

CONTROL STRATEGY

The series APF ought to be controlled with the end goal that the voltage injected by it ought to remunerate the sounds present in the framework and should help in improving the nature of energy. To accomplish the above reason, the yield voltage of the APF ought to be controlled. For this to happen, at initial a reference voltage is created which when injected by APF will fill the desired need. At that point the genuine yield voltage of the series associated APF is controlled using a PI controller with the end goal that the real yield voltage created is equivalent to the reference esteem. The general control system is appeared by the flow outline given in Fig. 2.

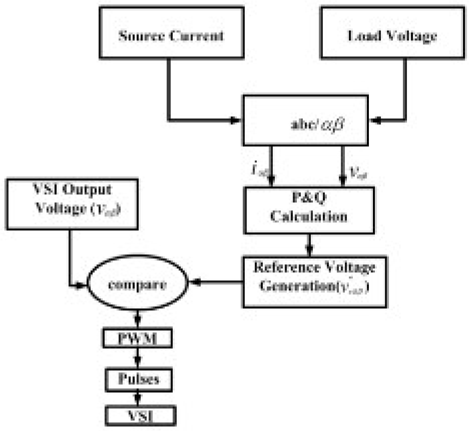

Fig 2: Flow Chart of Control Strategy.

SYSTEM ARCHITECTURE

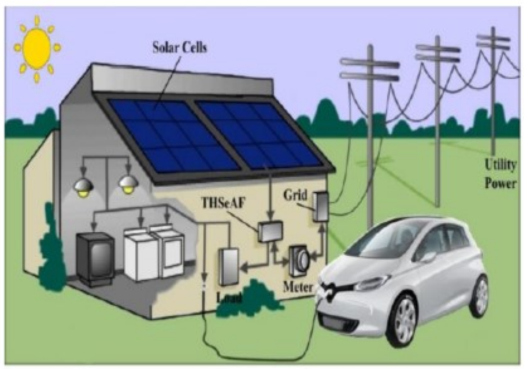

Fig (a)

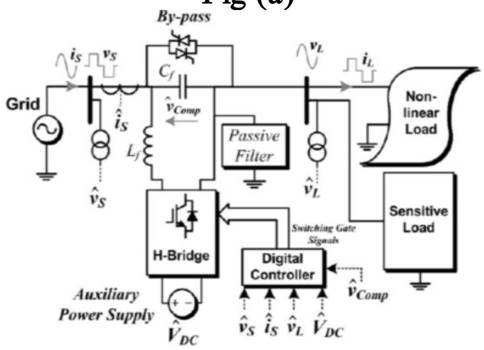

Fig (b)

Fig. 3:a) Schematic of a single-phase smart load with the compensator installation, b) Electrical diagram of the THSeAF in a single-phase utility.

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Operation Principle

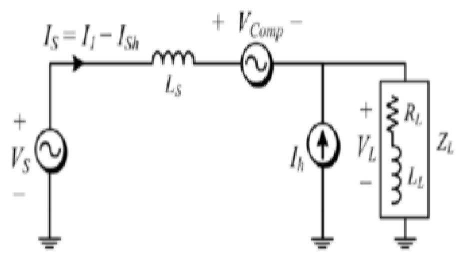

Fig.4: THSeAF equivalent circuit for current harmonics.

The series active filter operates as an ideal controlled voltage source (*Vcomp*) having a gain (*G*) proportional to the current harmonics (*Ish*) flowing to the grid (*Vs*).

$$v_{comp} = \mathbf{G}.\ I_{sh} - v_{lh} \quad (1)$$

This allows having individual equivalent circuit for the fundamental and harmonics:

$$v_{source} = v_{s1} + v_{sh}\ , \qquad v_L = v_{L1} + v_{Lh} \quad (2)$$

The source harmonic current could be evaluated.

$$v_{sh} = -Z_s.I_{sh} + v_{comp} + v_{Lh} \quad (3)$$

$$v_{Lh} = Z_L\ (I_h - I_{sh}) \quad (4)$$

Combining (3) and (4) leads to (5).

$$I_{sh} = \frac{v_{sh}}{G - Z_s} \quad (5)$$

If gain *G* is sufficiently large (*G→∞*), the source current will be come clean of any harmonics (*Ish→0*).This will help improving the voltage distortion at the grid side. In this approach the THSeAF behave as high impedance open circuit for current harmonics, while the shunt high pass filter tuned at the system frequency, creates low-impedance path for all harm on ics and open circuit for the fundamental ;it also help for power factor correction.

TABLEII

SINGLE-PHASECOMPARISONOFTHETHSEAFTOPRIORHSEAFS

Definition	Proposed THSeAF	[21]	[22]	[12]
Injection Transformer	Non	2 per phase	1 per phase	1 per phase
# of semiconductor devices	4	8	4	4
# of DC link storage elements	1+Aux. Pow.	1	2	1+Aux. Pow.
AF rating to the load power	10-30%	10-30%	10-30%	10-30%
Size and weight, regarding the transformer, power switches, drive circuit, heat sinks, etc.	The Lowest	High	Good	Good
Industrial production costs	The Lowest	High	Low	Low
Power losses, including switching, conducting, and fixed losses	Low	Better	Low	Low
Reliability regarding independent operation capability	Good	Low	Good	Good
Harmonic correction of Current source load	Good	Good	Good	Low
Voltage Harmonic correction at load terminals	Good	Better	Good	Good
Power factor correction	Yes	Yes	Yes	No
Power injection to the grid	Yes	No	No	Yes

MODELING AND CONTROL OF THE SINGLE-PHASE THSEAF:

A. Average and Small-signal Modeling

Based on the average equivalent circuit of an inverter, the small-signal model of the proposed configuration can be obtained as of Fig 6.1. Here after, *d* is the duty cycle of the upper switch during a switching period, whereasand denotes the average values in a switching period of the voltage and current of the same leg. The mean converter output voltage and current are expressed by (6) and (7) as follow.

$$\bar{v}_0 = (2d - 1)\_\_{}_m V_{DC} \quad (6)$$

$$\bar{i}_{DC} = \mathbf{m}\, \bar{i}_f \quad (7)$$

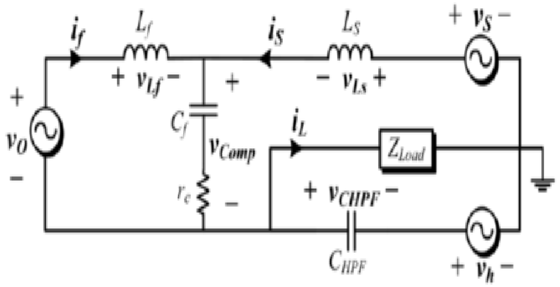

Fig 5.1 Small-signal model of transformer less HSeAF in seriesbetween the Grid and the load.

Calculating the Thevenin equivalent circuit of the harmonic current source leads to the following assumption.

$$\bar{v}_h(j\omega) = \frac{-j\,\bar{I}h}{C_{HPF}.\omega_h} \qquad \textbf{(8)}$$

If the harmonic frequency is high enough, it is possible to assume that there will be no voltage harmonics across the load. The state-space small-signal ac model could be derived by a linearized perturbation of averaged model as follow:

$$\dot{x} = \mathbf{Ax} + \mathbf{Bu} \qquad \textbf{(9)}$$

Hence we obtain:

$$\frac{d}{dt}[\bar{v}_{cf}\ \bar{v}_{CHPF}\ \bar{i}_s\ \bar{i}_f\ \bar{i}_L] = [\,]X[\bar{v}_{cf}\ \bar{v}_{CHPF}\ \bar{i}_s\ \bar{i}_f\ \bar{i}_L]$$

$$+[\,]\mathbf{X}[\bar{v}_s\ v_{DC}\ \bar{v}_h] \qquad \textbf{(10)}$$

And the output vector is:

$$Y = Cx + Du \text{.........................}(11)$$

Or

$$[n_{comp} n_L] = [\,]X[n_{cf} n_{CHPF} i_S\ i_f\ i_L] + 0000-\ 1]X[v_S v_{DC} v_h]\text{............}(1\!2$$

By means of (10) and (12), thestate-space representation of the model is obtained as shown in Fig 6.1.

The transfer function of the compensating voltage versus the load voltage, $T_{V\_CL}(s)$, and the source current, $T_{CI}(s)$, are developed in the appendix. Mean while, to controlhe active part independently the derived transfer function should be autonomous from the grid configuration. The transfer function T_{Vm} presents the relation between the output voltages of the converter versus the duty cycle of the first leg converter's upper switch.

$$T_v(S) = \frac{v_{comp}}{v_0} = \frac{r_c c_f s+1}{L_f c_f s^2 + r_c c_f S+1} \qquad \textbf{(13)}$$

$$T_{vm}(S) = \frac{v_{comp}}{v_m} = V_{DC} \cdot T_V(S) \qquad \textbf{(14)}$$

Further detailed derivation of steady-state transfer functions are described in the section V.

A DC auxiliary source should be employed to maintain an adequate supply on the load terminals. During the sag or swell conditions, itshould absorb or inject power to keep the voltage magnitude at the load terminals within a specified margin. However, if the compensation of sags and swells is less imperative, a capacitor could be deployed. Consequently, the DC-link voltage across the capacitor should be regulated as demonstrated in Fig 5.

Voltage and Current Harmonic Detection

The outer-loop controller is used where a capacitor replaces the DC auxiliary source. This control strategy is well explained in the previous section. The inner-loop control strategy is based on an indirect control principle. A fast Fourier transformation (FFT) was used to extract magnitude of the fundamental and its phase degree from current harmonics. The control gain ***G*** representing the impedance of the source for current harmonics, has a sufficiently level to clean the grid from current harmonics fed through the non-linear load.

The second PI controller used in the outer loop, was to enhance the effectiveness of the controller when regulating the DC bus. Thus a more accurate and faster transient response was achieved without compromising compensation behavior of the system. According to the theory, the gain G should be kept in a suitable level, preventing the harmonics flows into the grid framework [22,24]. As previously discussed, for a more precise compensation of current harmonics, the voltage harmonics should also be considered. The compensating voltage for current harmonic compensation is obtained from (15).

$$v_{comp\_i}(t) = (-G\hat{i}_s + \hat{v}_L) - [|-Gi_{z1} + v_{L1}|.\sin(w_s t - q)] \quad \text{............(15)}$$

Here by, as voltage distortion at the load terminals is not desired, the voltage sag and swell should also be investigated in the inner-loop. The closed loop equation (16) allows to indirectly maintain the voltage magnitude at load side equal to VL^* as a predefined value, within acceptable margins.

$$v_{comp\_v} = v^*_L \sin(\omega_s t) \quad \text{(16)}$$

The entire control scheme for the THSeAF presented in Fig. 5was used and implemented in MATLAB/ Simulink for real-time simulations and calculation of the compensating voltage. The real-time tool box of dSPACE was used for compilation and execution on the dsp-1103 control board. The source and load voltages together with the source current are considered as system input signals. According to [25] , an indirect control increases the stability of the system.

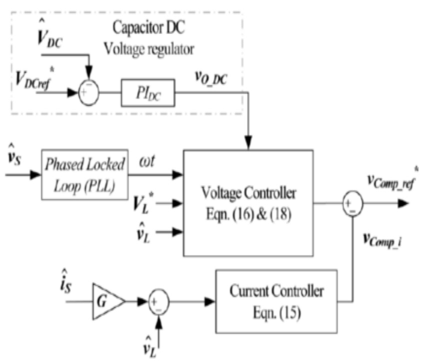

Fig 5.2 Control system scheme of the active part.

The source current harmonics are obtained by extracting the fundamental component from the source current.

$$v^*_{comp\_ref} = v_{comp\_v} - v_{comp\_i} + v_{DC\_ref} \quad \text{(17)}$$

Where the VDC_ref is the voltage required to maintain the DC bus voltage constant.

$$v_{DC\_ref}\text{ (t)} = v_{0\_DC} \cdot \sin(\omega_s t) \quad \text{(18)}$$

A phase-locked loop (PLL) was used to obtain the reference angular frequency (ω_S). Accordingly, the extracted current harmonic $\hat{i}_{Sh}$ contains a fundamental component synchronized with the source voltage in order to correct the power factor (PF). This current represents the reactive power of the load. The gain G representing the resistance for harmonics converts current into a relative voltage. The generated reference voltage $Vcomp\_i$ required to clean source current from harmonics is described in (15).

According to the presented detection algorithm, the compensatedreference voltage is calculated. Thereafter, the reference signal is compared with the measured output voltage and applied to a PI controller to generate the corresponding gate signals as in Fig 5.3.

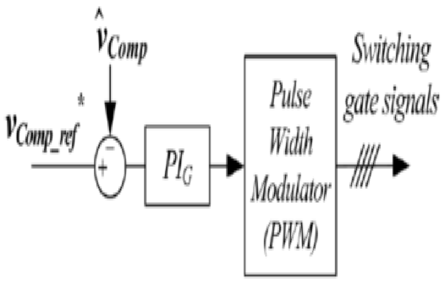

Fig.5.3 Block diagram of THSeAF and PI controller.

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Analysis for Voltage and Current Harmonics

The stability of the configuration is mainly affected by the introduced delay of a digital controller. This subsection studies the impact of the delay first on the inclusive compensated system according to works cited in the literature. Thereafter, its effects on the active compensator separated from the grid. Using purely inductive source impedance and the Kirchhoff's law for harmonic frequency components, (19) is derived. The delay time of digital controller, large gain G and the high stiffness of the system seriously affect the stability of the closed-loop controlled system.

$$I_{sh}(t) = \frac{V_{sh} - V_{comp} - V_{Lh}}{L_s s} \quad (19)$$

The compensating voltage including the delay time generated by the THSeAF in Laplace domain (see Eqn. (1)) is

$$v_{comp} = G. I_{sh} . e^{-\tau s} - V_{Lh} \quad (20)$$

considering (19) and (20), the control diagram of the system with delay is obtained as in Fig 5.4.

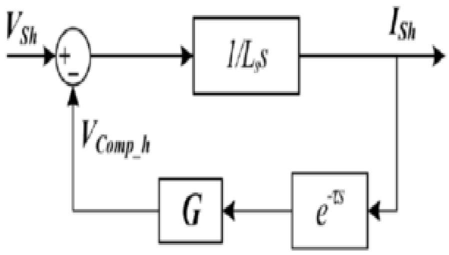


Fig 5.4Thecontrol diagram of the system with delay.

For the sake of simplicity, overall delay of the system is assumed to be a constant value τ. Therefore, the open-loop transfer function is obtained.

$$G(s) = \frac{G}{L_s S} e^{-\tau s} \quad (21)$$

From the Nyquist stability criterion, the stable operation of the system must satisfy the following condition:

$$G < \frac{\pi L_s}{2\tau} \quad (22)$$

A system with a typical source inductance *Ls*of 250 µH and a delay of 40 µs is considered stable according to (22), when the gain ***G*** is smaller than 10Ω. Experimental results confirm the stability of system presented in this work. Moreover, the influence of the delay on the control algorithm should also be investigated. According to the transfer functions (13) and (14), the control of the active part is affected by the delay introduce by the digital controller. Thus, assuming an ideal switching characteristic for the IGBTs, the closed-loop system for the active part controller is shown in Fig. 5.5.

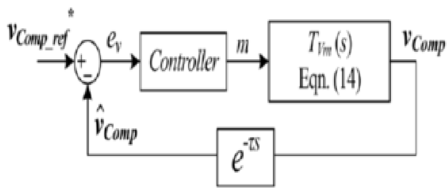


Fig.5.5Closed-loop control diagram of the Active filter with a constant delay time *τ*.

The open loop transfer function in Fig 5.5 turns to (23), where, the τ is the delay time in initiated by the digital controller.

$$F(s) = P I_G . T_{vm} . e^{-\tau s}$$

$$= \frac{(r_C c_f V_{DC} s + V_{DC}).(k_p s + k_i) e^{-\tau s}}{s.(L_f c_f s^2 + r_C c_f S + 1)} \quad (23)$$

SIMULATION CUIRCUIT DIAGRAM

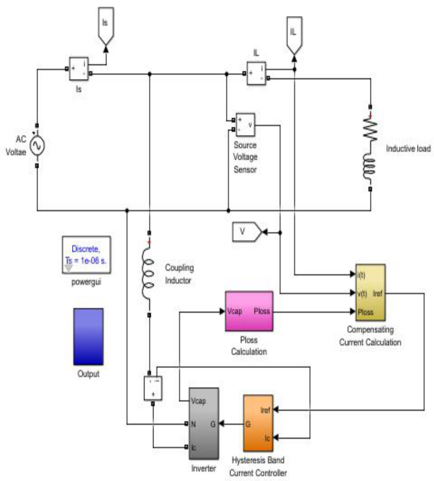
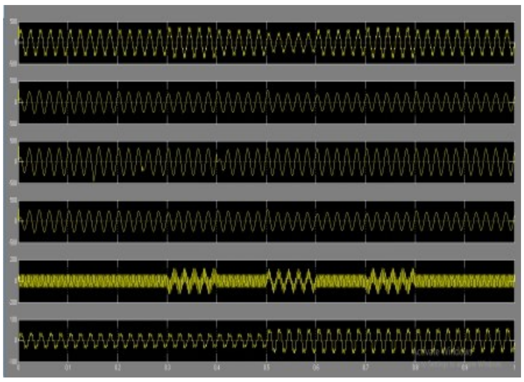


Fig 6. Proposed simulation circuit.

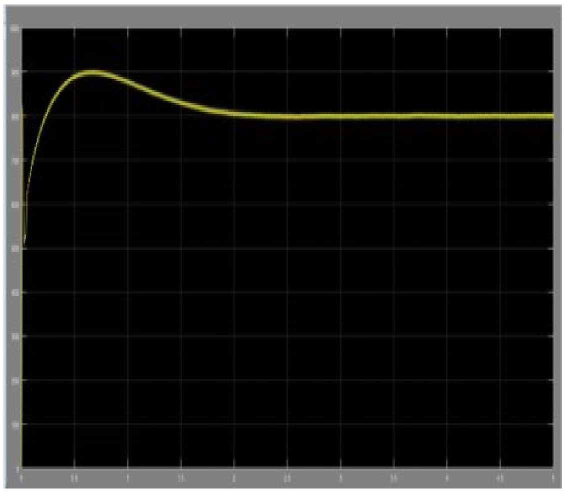
SIMULATION RESULTS OF PROPOSED SYSTEM

The proposed Transformer less - HSeAF configuration was simulated in



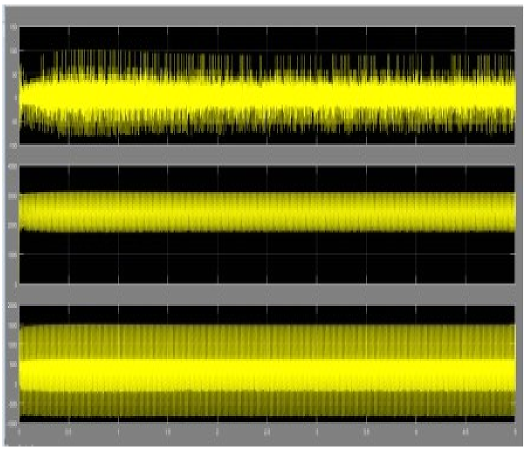
→Time(s)

Fig.7.1 Simulation of the system with the THSeAF compensating current harmonics and voltage regulation.(a) Source voltage *vS*, (b) sourcecurrent *iS*, (c) Load voltage*L*,(d) Loadcurrent *iL*, (e) Active-filter voltage *VComp*,(f) Harmonics current of the passive filter



→Time(s)

Fig.7.2 capacitor voltage



→Time(s)

Fig.7.3 (a) source voltage, (b) source current, (c) load current,

CONCLUSION

In this Paper a Transformer less-HSeAF for power quality improvement was developed and tested. The project highlighted the fact that with the ever increase of non-linear loads and higher exigency of consumer for are liable supply, concrete actions should be taken into consideration for future Smart Grids in order to smoothly integrate electric cars battery chargers to the grid. The key novelty of the proposed solution is that the proposed configuration could improve power quality of the system in more general way by compensating a wide range of harmonics current. Even though, it can be seen the THSeAF regulates and improves the PCC voltage. Connected to are new able auxiliary source, the topology is able to counteract actively to the power flow in the system. This essential capability is required to ensure a consistent supply for critical loads. Behaving as high-harmonic impedance, it cleans the power system and ensures a unity power factor. The theoretical modeling of the proposed configuration was investigated. The proposed transformer less configuration was simulated and it was demonstrated that this active compensator responds properly to source voltage variations by providing a constant and distortion-free supply at load terminals. Furthermore, it eliminates source harmonic currents and improves power quality of the grid without the usual bulky and costly series transformer.

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